BACK TO BASICS

Voting Thrust Measurements with Other Parameters

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Although the practice of voting thrust position alarms with other parameters, such as bearing temperature, is sometimes seen in the field, Bently Nevada does not recommend it. Proponents of voting between dissimilar measurements generally do so because they believe it helps guard against false alarms (after all, two independent measurements can't both be wrong – can they?). However, there are numerous pitfalls to such an approach, which we'll review below.

Thrust Position Protection – A Review

Thrust position is an extremely critical measurement in rotating machinery. When a thrust bearing fails, axial movement of the shaft is no longer constrained and must instead be absorbed by some other part of the machine. Sometimes this is a seal, but seals are not designed to support load and they quickly fail under such conditions. More often, the uncontrolled axial movement will simply allow rotating and non-rotating elements to come in contact, such as blades contacting static elements. The results are catastrophic to the machine and the process, and can be a serious safety risk to personnel. There are documented cases of thrust bearing failures leading to fatalities.

Thrust position can also change very rapidly. Although it is not a good design, some machines employ thrust collars that are not an integral part of the shaft. If the thrust collar comes loose, thrust position can change almost instantaneously, allowing operators little time to react and engage a manual machine shutdown. Finally, because thrust position is a non-subjective measurement (alarm limits are directly related to axial clearances in the machine and/or allowable thrust bearing wear), there is little point in relying upon interpretation and manual review of thrust alarms before engaging a machine shutdown sequence. Unlike other types of machinery measurements, where the question "how much is too much?" can be subjective, the decision of how much axial movement is permissible is straightforward.

For all of these reasons, Bently Nevada recommends that customers continuously measure axial position and tie the Danger alarms from such a measurement to automatic machine shutdown. In some cases, certain processes can be dangerous or unstable if a machine is shut down suddenly, and thrust alarms are more appropriately tied to a sequencer that brings the machine down slowly (if possible), rather than an instantaneous trip. However, the *initiation* of a machine shutdown due to excessive thrust movement can (and should) be made instantaneously, regardless of how long it takes to bring the process and machine to a halt.

Dual Voting

The nature of a thrust position measurement is that it observes the gap between the probe tip and the observed surface, usually the end of a shaft or a thrust collar (Figure 1). Because the OK circuitry of a machinery protection system uses gap voltage as a measure of the transducer's integrity, a NOT OK condition (gap voltage out of range) in a thrust position measurement may simply indicate that thrust position has moved so far that the gap is out of the transducer's acceptable range. There is not a problem with the transducer – there is a problem with a machine. This is rarely a problem with radial vibration measurements, as radial motion is constrained to much smaller distances than with axial measurements, and a radial gap will never exceed the OK limits unless there is a bona-fide transducer problem. Because a thrust position failure can exhibit the same characteristics as a transducer failure (excessive gap voltage), a scheme whereby false trips and missed trips can be simultaneously minimized must be used.

The practice of *dual-voting* thrust measurements is widely employed – and is globally recognized as minimum acceptable practice for thrust position protection. Two thrust probes are installed, each observing the same motion of the shaft or collar. When operating correctly, each probe is

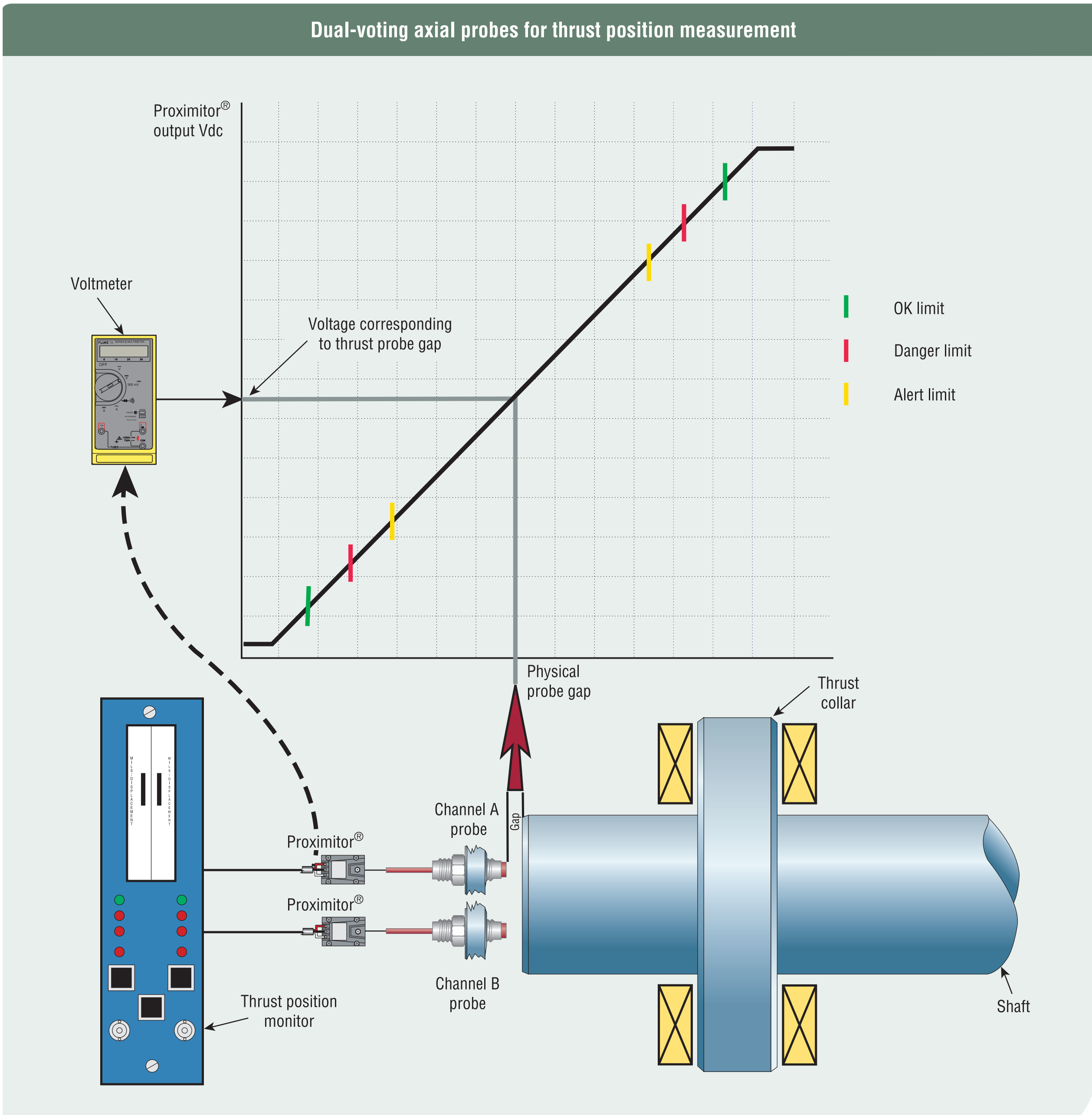

Figure 1.

observing the same motion, and each should display the same movement. By employing AND voting (both probe A *and* probe B must exceed their DANGER alarm levels at the same time), the objective of minimizing false trips and missed trips can be realized. With only a single probe, the ability to distinguish between a transducer failure and genuine excessive thrust movement is lost. However, when two probes are installed, the likelihood that both transducers will fail simultaneously is low and activation of the DANGER relay (or digital output) takes place under the conditions shown in Figure 2.

Indeed, under condition B where both transducers have failed (or the axial position has legitimately moved so far that the probes are both outside their linear range), most machinery operators want to remove the machine from service anyway, since they are operating without protection or even indication of thrust position. Conversely, if only one transducer indicates excessive axial movement (gap), and

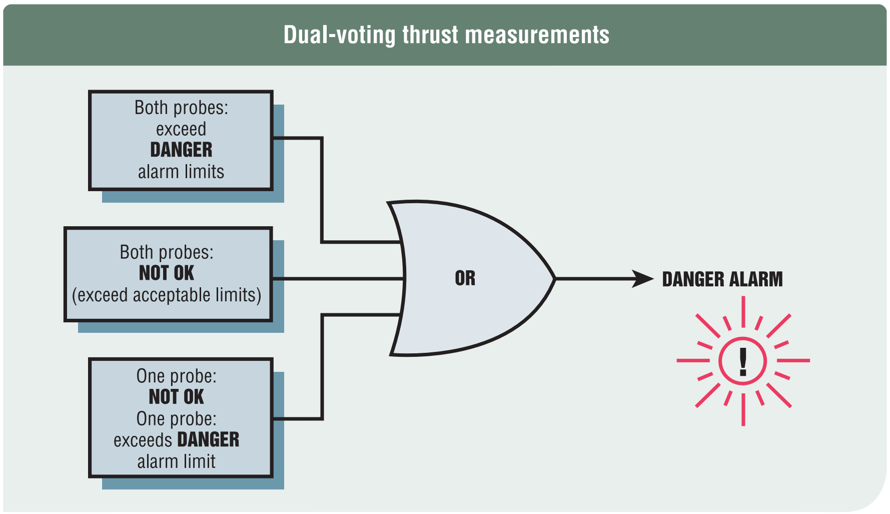

Figure 2.

the other does not, it can be reasoned that the transducer is faulty, since both should always read the same (both are observing the same relative motion).

Proponents of 2-out-of-3 voting use mathematical probability arguments to show that it provides the optimal balance of false trips and missed trip protection. However, it is rarely practical to install three axial transducers in a single thrust bearing due to space constraints. Also, 2-out-of-3 voting schemes don't typically take into account the considerations of transducer self-checking capability (NOT OK detection). This raises the integrity of a 2-out-of-2 (AND voting) system relative to a system with "dumb" (non- self-checking) inputs. Thus, simple 2-out-of-2 (AND) voting has become the industry norm for thrust position measurements.

Voting with Other Parameters

While the dual-voting convention for thrust measurements provides a very high-integrity approach to both false trips and missed trips, as mentioned previously, some still prefer to vote their thrust position alarms with bearing temperature or other measurements.

The following scenarios help to illustrate why this is inadvisable:

1. Loose or broken thrust collar:

   When a thrust collar becomes loose, the shaft is free to move independently of the thrust collar. If proximity probes are observing the end of the shaft, they will correctly show the axial movement. However, the thrust collar will no longer be transferring axial load to the thrust bearing and the bearing temperature may remain the same or actually *drop*. Therefore, an axial alarm may occur but not a temperature alarm. Thus, axial position and temperature may not always jointly indicate a bearing failure.

   Such a condition occurred several years ago on a large compressor train in a North American gas processing plant, and the subsequent failure resulted in a fatality. The same plant later destroyed the rebuilt machine because the operators ignored the high thrust position alarms when thrust bearing temperature once again did not indicate any abnormalities. Fortunately, in this second occurrence, the damage involved only the machine – not human life. Subsequently, the Bently Nevada thrust monitors were finally connected to automatic shutdown without any intervening temperature voting.

2. Axial rub:

   Sometimes, a severe thrust bearing failure will allow an axial rub to occur. This axial rub effectively unloads the thrust bearing by allowing the rubbing parts to absorb some of the thrust load. In this case, the thrust bearing pads will actually decrease in temperature as the bearing failure progresses, and will not always go through a high enough temperature to initiate any temperature alarms.

3. Bearing failure:

   Failures can occur in a thrust bearing where the pads or bearing components deteriorate due to electrostatic discharge (see page 23), metallurgical issues, or other reasons. These do not necessarily result in a failure mechanism where a pad becomes more heavily loaded and its temperature increases. Axial position is a much more reliable indicator of thrust bearing problems.

4. Pad temperature gradients:

   Depending on where the temperature sensors are embedded in the thrust bearing pads, large differences in temperature can occur over the pad's geometry. For example, a pad will generally experience the highest temperatures at the edge of the pad where most of the load is carried. Temperature variations of 40 or 50 degrees F are not uncommon across a pad. Thus, a pad could experience significant heating during a failure, but

the location of the temperature sensing element may not always capture the true temperature at the place where Babbitt is breaking down or load is most concentrated. This means that Babbitt could be melting at one edge of a pad, yet temperatures could be much lower – even normal – at the other edge of a pad. Depending on where the temperature sensors were located, they may not generate any alarms.

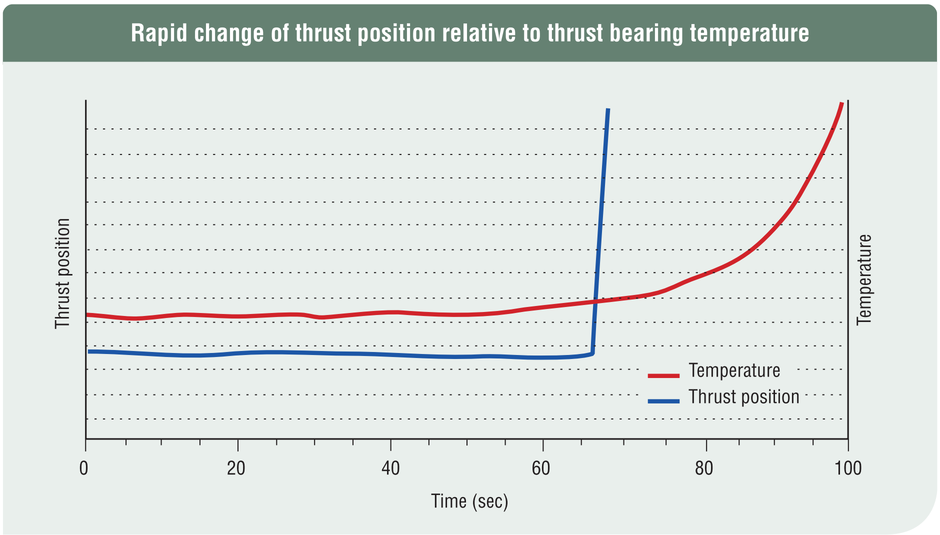

Figure 3.

5. Temperature Response:

   Bearing metal has a thermal inertia that generally introduces a delay between the onset of bearing failure and a corresponding increase in bearing metal (Babbitt) temperature. Even though the temperature response may take just a few seconds, this is still much longer than the response time for a position measurement made with proximity probes. One of many examples encountered over the years comes from a recent customer report. While the axial probes detected excessive movement instantly, bearing temperature change was not indicated for three seconds (*after* the bearing surface was completely melted away!), and even then only started to climb slowly (Figure 3). Finally, after 30 seconds the machine was shut down manually. Fortunately, the damage was limited to a destroyed thrust collar and bearing. It could have been much worse. The root cause of the bearing failure was later determined to be faulty connections to the balance piston, and the thrust bearing was consequently required to absorb an axial load in excess of its capacity. Instantaneous shutdown would likely have saved the bearing and the thrust collar. This failure introduced extended downtime at a cost of over 250,000 USD per day.

   As noted above, excessive axial movement leaves very little room for interpretation or subjectivity, provided the position alarms have been established correctly in the first place. In a thrust failure, every second is important and using the fastest measurement available (axial position as measured by proximity probes) as the primary means of shutdown protection is advisable. The customer noted above has since connected all thrust alarms directly to shutdown, without any intervening voting logic using temperature or other parameters.

Economic Considerations

While the reasons for shutting down as quickly as possible on excessive thrust movement are firmly rooted in safety concerns, there are also economic considerations. Other recent customer reports have documented how alarms from Bently Nevada monitors that are not acted upon can allow excessive thrust movement or radial vibration to occur for many minutes, hours, or even days. During these events, seal clearances are often enlarged due to excessive movement of the shaft. Even if the bearing is not destroyed, these enlarged clearances represent a loss of efficiency. Compounded over months or years, this loss of efficiency can represent hundreds of thousands, or even millions, of dollars.

Summary

Dual-voting thrust measurements represent a high integrity measurement of this important machinery parameter. Efforts to vote this measurement with other alarms in the machine rarely yield an acceptable balance between missed trips and false trips. When making thrust measurements, therefore, always employ two probes in a dual-voting configuration, and carefully consider the implications of voting thrust alarms with other parameters. As the examples in this article indicate, improper voting can be both unsafe and expensive.